Wind-Diesel Hybrid System Options for Alaska

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Wind-Diesel Hybrid Power Systems

- Basic Concept

  A wind-diesel hybrid system combines wind turbine(s) with diesel generator(s) to obtain a maximum contribution by the intermittent wind resource while providing continuous high quality electric power.

- Objectives
  - Reduce system fossil fuel consumption
  - Reduce diesel run time (high penetration systems only)
- Benefits
  - Reduced system operating costs
  - Reduced environmental impacts

Why Wind-Diesel?

Diesel:

- Large installed base of diesel power plants
- Lots of diesel operating experience
- Existing fuel and service infrastructure
- Relatively low capital cost compared to other dispatchable generators
- Since the objective is to use the generator as little as possible, it's important to minimize its cost.

Why Wind-Diesel?

Wind Turbines:

- Wind is a totally clean indigenous energy source.
- Wind power is the least cost of all renewables (except for large hydro).
- Many Alaskan coastal regions have an excellent wind resource year round.
- With the right equipment, wind turbines are relatively easy to install.
- With proper training, a typical diesel mechanic can handle most maintenance and repair procedures.
- Wind energy is mature technology.

Definition of Wind Penetration

$$\text{Instantaneous Penetration} = \frac{\text{Wind Power Output (kW)}}{\text{Primary Electrical Load (kW)}}$$

$$\text{Average Penetration} = \frac{\text{Wind Energy Produced (kWh)}}{\text{Primary Energy Demand (kWh)}}$$

Classification of Wind-Diesel Hybrid Systems by Wind Penetration

PENETRATION CLASS	OPERATING CHARACTERISTICS	PENETRATION	
		PEAK INSTANTANEOUS	ANNUAL AVERAGE
LOW	• Diesel runs full time • Wind power reduces net load on diesel • All wind energy goes to primary load • No supervisory control system	< 50%	< 20%
MEDIUM	• Diesel runs full time • At high wind power levels, secondary loads dispatched to ensure sufficient diesel loading • Alternatively, wind turbines are curtailed during high winds and low loads • Requires relatively simple control system	50 – 100%	20 – 50%
HIGH	• Diesels may be shut down during high wind availability • Auxiliary components required to regulate voltage and frequency • Requires sophisticated control system	100 - 400%	50 – 150%

Kotzebue Electric Association
Low Penetration Wind-Diesel System

- Application: Village power system
- Operating with ten turbines since spring 1999

Kotzebue Wind-Diesel System Performance Summary

- Diesel Power Plant: 11.2 MW
- Village load:
  - 2.5 MW average
  - 1.8 MW minimum
  - 3.9 MW peak
- Wind Turbine Capacity: 650 kW
  - Ten AOC 15/50 kW turbines
- Average wind penetration: ~ 6%
- Peak power penetration: ~ 35%
- KEA plans expansion to 2-3 MW of wind turbine capacity

St. Paul High Penetration, No Storage Wind-Diesel System

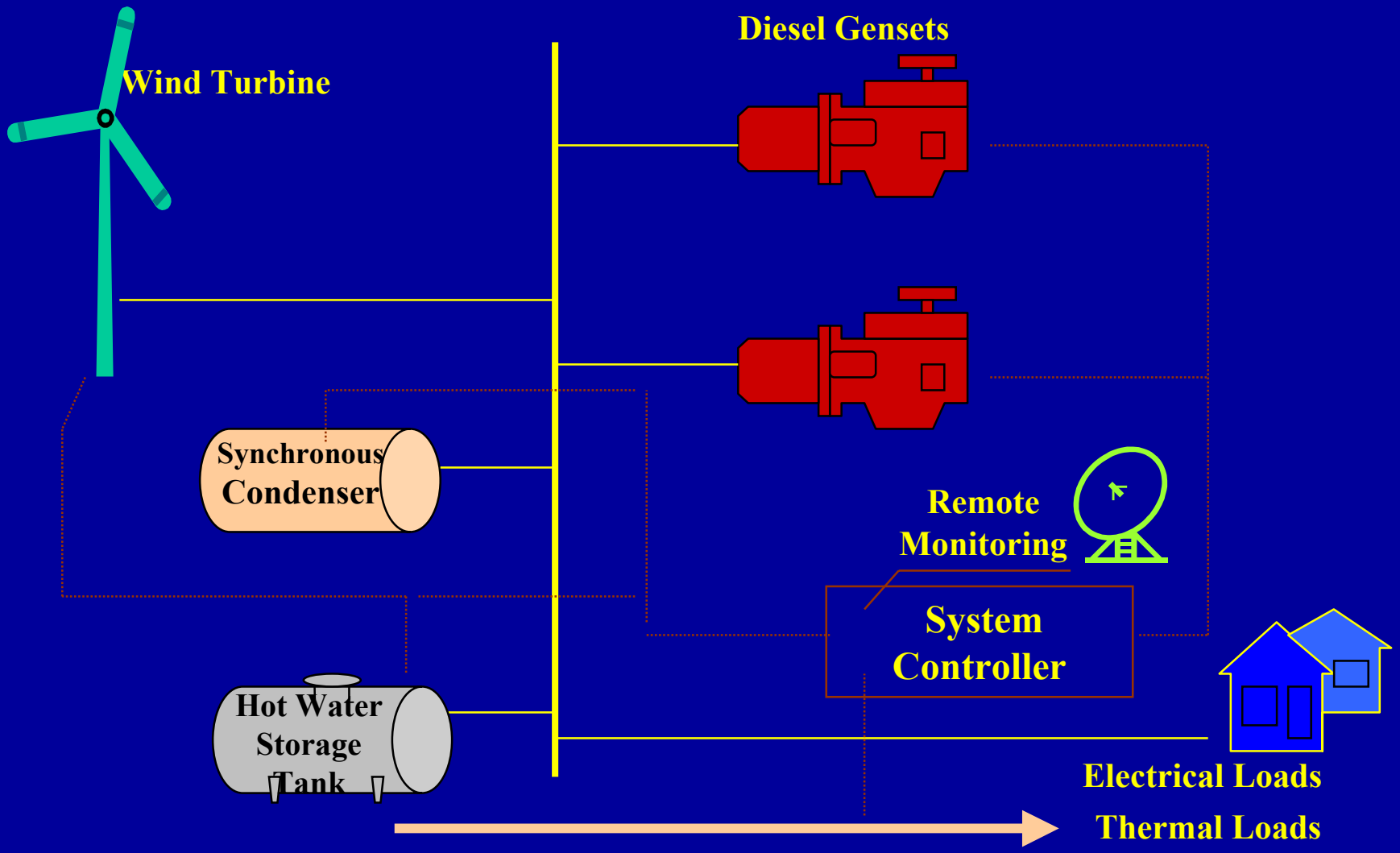
Application: Power system to serve electrical and thermal loads at an industrial/airport facility

Operating since June 1999

St. Paul High Penetration, No Storage Wind-Diesel System

- Diesel Power Plant: (2) 150 kW diesel gensets
- Primary load:
  - ~ 70 kW average
  - ~ 160 kW peak (with load growth planned)
- Wind Turbine Capacity: (1) 225 kW wind turbine
- Additional Components:
  - 300 kVA Synchronous Condensor
  - 446 kW electric hot water tank (Secondary Load)
  - System Control
- Average annual penetration: ~ 100%
- Peak penetration: > 400%

St. Paul Wind-Diesel System Architecture



Wales High Penetration Wind-Diesel System with Short Term Energy Storage

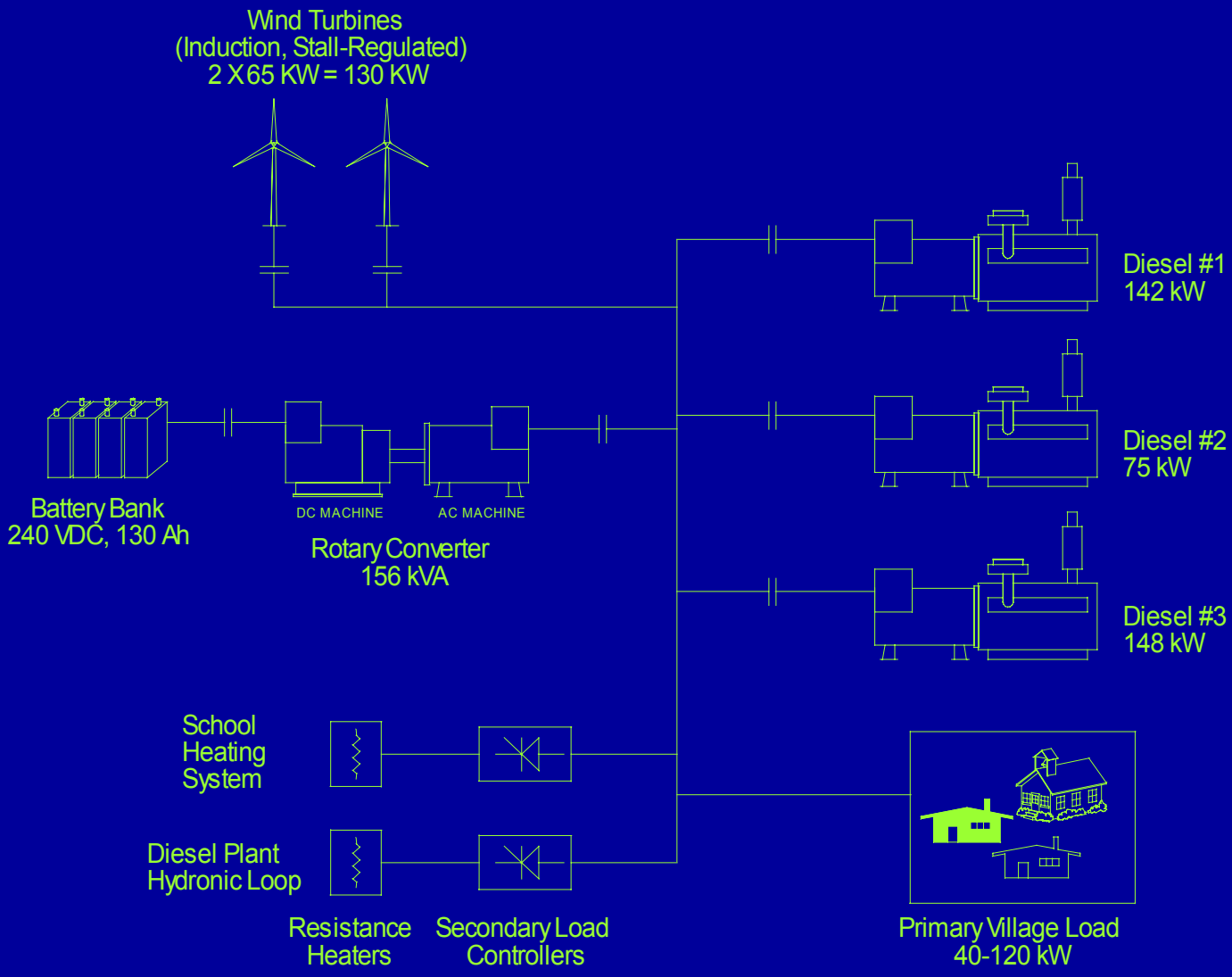
Application: Village Power System

In partial operation since October 2000

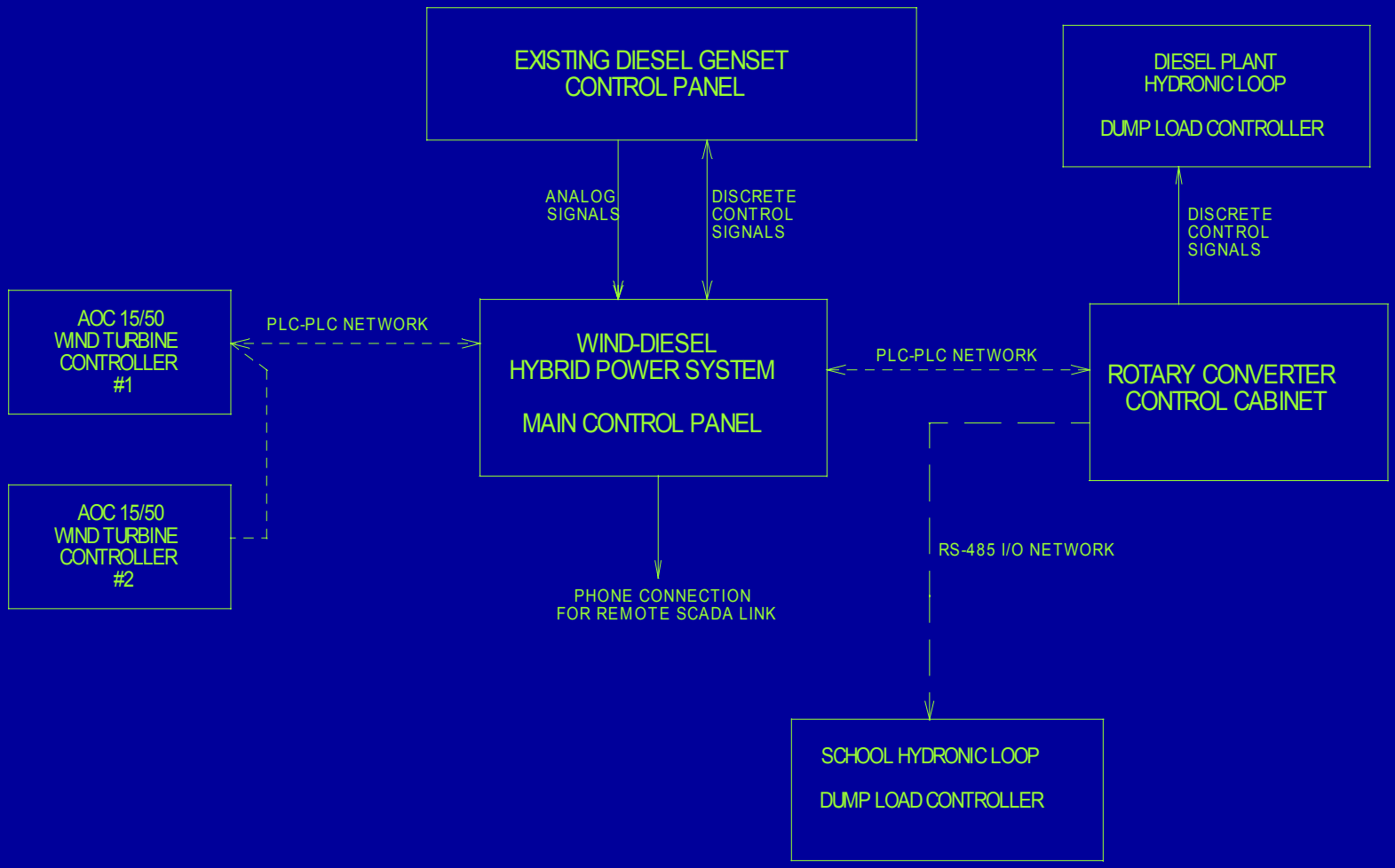
Wales High Penetration Wind-Diesel System with Short-Term Energy Storage

- Diesel Power Plant: (2) 168 kW + (1) 75 kW = 411 kW
- Primary load:
  - ~ 70 kW average
  - ~ 140 kW peak
- Wind Turbine Capacity: (2) 65 kW wind turbines
- Additional Components:
  - 156 kVA Rotary Converter
  - 31 kWh Battery Bank
  - 234 kW Electric Boiler Secondary Loads System Controls
- Average annual penetration: ~ 100%
- Peak penetration: ~ 350%

Wales Wind-Diesel System Architecture



Wales Wind-diesel System Communication And Control



Review of Wind-Diesel Classes

Low Penetration

- Lowest capital cost
  - ($1,000-1,500/ kW wind capacity, excluding diesel plant)
- Easiest to integrate with existing diesel system
- No diesel plant modifications necessary
- Only modest fuel savings possible: up to ~20%
- Additional support requirements:
  - Wind turbine maintenance

Review of Wind-Diesel Classes

Medium Penetration

- Higher capital cost
  - ($1,500-2,500/ kW wind capacity, excluding diesel plant)
- Some diesel controls modifications necessary
- Automated diesel operation desirable
- Usually must install/integrate secondary loads
- Requires relatively simple supervisory control
- Greater fuel savings possible: up to ~40%
- Additional support requirements:
  - Wind turbine maintenance
  - Secondary load maintenance
  - Basic control system troubleshooting

Review of Wind-Diesel Classes

High Penetration

- Highest capital cost
  - ($2,500-4,000/ kW wind capacity, excluding diesel plant)
- Significant diesel controls modifications may be necessary
  - New diesel control panels highly recommended
- Must install/integrate secondary loads
- Requires sophisticated supervisory control system
- Highest fuel savings possible: up to ~70%
- Additional support requirements:
  - Wind turbine maintenance
  - Secondary load maintenance
  - Advanced control system troubleshooting

Conclusions

- Several distinct approaches to wind-diesel exist, each with its own architecture
- Higher wind penetration means higher capital cost but lower operating cost and greater fuel savings
- High penetration systems have greater complexity and require greater technical sophistication
- Training and support infrastructure essential
- Given good wind resource and adequate project density, high penetration wind-diesel systems can provide least life cycle cost of electricity in remote communities.